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LIVING NOISE BARRIER
FINAL REPORT

JANUARY 1998

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16. Abstract

In the late 1980's, the Wisconsin Department of Transportation (WisDOT) became aware of "living" noise barriers being used along European roadways. After corresponding with German colleagues and completing a feasibility study, WisDOT undertook an experimental project to construct a 158 meter (520 foot) long living noise barrier. The structure consisted of a recycled plastic frame filled with soil and planted with vegetation.

The barrier was evaluated over a 2-year period for structural performance, maintainability, aesthetic appearance, vegetation performance, public opinion, and costs. This report documents the investigation, design, construction, and the gradual deterioration of the structure. The project was terminated after a 30 meter (100 foot) section of the barrier collapsed. Based on the results of this study, it is concluded that living noise barriers are not cost effective and should not be pursued by WisDOT. Furthermore, based on the strength and temperature characteristics of plastic, WisDOT's experience with Recywall, and other instances where plastics were used in a structural capacity, it is the recommendation that non-reinforced plastics, either virgin or recycled, not be used as structural members of any kind.

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LIVING NOISE BARRIER

FINAL REPORT WI/FEP-01-98
Federal Experimental Project # WI 93-02

by

Robert Schmidt, P.E.
Environmental Engineer
Wisconsin Department of Transportation
Transportation District 2
Environmental Services Unit
141NW Barstow St., Waukesha, WI 53187-0798

for

WISCONSIN DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION INFRASTRUCTURE DEVELOPMENT
BUREAU OF HIGHWAY CONSTRUCTION
PAVEMENT RESEARCH UNIT
3502 KINSMAN BLVD., MADISON, WI 53704-2507

Study Manager
Debra Bischoff, Research Engineer

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The Pavement Research Unit of the Division of Transportation Infrastructure Development, Bureau of Highway Construction, under the direction of the Council on Research, conducts and manages the highway engineering research program of the Wisconsin Department of Transportation. The Federal Highway Administration provides financial and technical assistance for these research activities, including review and approval of publications. This publication does not endorse or approve any commercial product even though trade names may be cited, does not necessarily reflect official views or policies of the agency, and does not constitute a standard, specification or regulation.

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INTRODUCTION

In the late 1980’s, the Wisconsin Department of Transportation (WisDOT) saw an increasing demand by elected officials and from the public for noise barriers along the Milwaukee area freeway system. Up until that time, WisDOT had built several noise barriers out of various materials. Barriers had been constructed out of wood, metal, and concrete with a number of different surface textures and finishes. Although effective in reducing freeway noise, the barriers were quite expensive and reaction to their aesthetic appearance was mixed at best. Many residents complained that the barriers resembled prison walls or industrial warehouses. Landscaping efforts were fairly effective in improving their aesthetic appearance, but also increased the cost of barrier projects.

Also in the late 1980’s, WisDOT became aware of “living” noise barriers in use in Germany, Denmark, and the Netherlands. These barriers consisted of a composite retaining wall section made of two “fences” of woven live willow branches with a rich organic soil filling the void between the fences. After a few months, the willow branches would “green out” and eventually look like a tall hedge.

After further investigation and correspondence with German colleagues, WisDOT determined that it would be worthwhile to undertake a study to determine if “living” noise barriers could be a maintainable, cost-effective, and aesthetically pleasing alternative to standard post and panel type noise barriers.

Following the decision to proceed with this study, the City of Milwaukee requested that WisDOT construct a demonstration living noise barrier within the city limits. Considering both local and departmental support, WisDOT District 2, Waukesha, procured the consulting services of Howard, Needles, Tammen, and Bergendoff (HNTB) to undertake a 2-phased investigation of living noise barriers.

FEASIBILITY STUDY

Phase One of the investigation was to conduct a living noise barrier feasibility study. This study was to evaluate existing living noise barrier systems, determine vegetation types suitable to the local climate and freeway conditions, consult with public agencies to determine their experiences with living barriers, and determine if a demonstration living noise barrier project would be feasible.

The study was concluded in the summer of 1993, and determined that a demonstration living noise barrier project would be feasible. It also recommended that an existing system called "Recywall" be used to construct the barrier. This system was selected for its ease of construction, use of recycled materials (plastic), minimal base width requirements, and optimum water collection compared with other systems.

Recywall is a soil retaining structure made from recycled plastic. The interlocking vertical supports and horizontal planks are put together on site and progressively filled with soil. After the structure is erected, the soil areas, or planting cells, are planted with vegetation which grows and eventually covers the plastic framework.

A location was identified for the demonstration project along the west side of I-94, north of College Avenue in Milwaukee Wisconsin. A length of 158 meters (520 feet**)** of living barrier would be constructed at the south end of a 573 meter (1880-foot) standard post and panel noise barrier. The project location is shown in Figures 1 and 2 (pages 14 and 15) and the preliminary conceptual design is shown in Figure 3 (page 16).

The original willow branch system was dropped from consideration early in the study. This system is very labor intensive to construct, would not accommodate barrier heights greater than 3.6 meters (12 feet), and would require willow tree resources which are not readily available in this area.

BARRIER DESIGN AND CONSTRUCTION

DESIGN

Phase Two of the investigation was to prepare the contract document for the demonstration project. This phase was performed by HNTB staff.

HNTB staff prepared plans and specifications including foundation design, barrier profile, horizontal alignment and planting plans. The manufacturer of Recywall, Sanders Enterprises, Inc. (SEI), prepared the design and shop drawings for the plastic structure itself.

The foundation design included a compacted sub-base, a geogrid, and 450 mm (18 in.) of crushed aggregate. The foundation design allowed for dispersing the load of the vertical support members of the barrier.

The bottom profile of the barrier was designed to follow the general profile of the existing ground. The barrier required a level surface with several 1-meter (3-foot) steps. The top profile of the barrier was designed to reduce traffic sound levels behind the barrier by 8 decibels. The FHWA traffic noise prediction model, STAMINA, was used to obtain the required top elevations. The maximum height of the structure was 6.4 meters (21 feet).

SEI's final design and shop drawing differed somewhat from the preliminary design. The base width of the structure was reduced from 2.7 meters (9 feet) to 2.1 meters (7 feet) in order to match SEI's standard mold and to save on material costs. The slope of the face of the structure was also reduced from 1:5.25 to 1:7 with several sections having a vertical face. Figures 4 and 5 (pages 17 and 18) show the final design.

WisDOT expressed concern regarding the steeper faces and reduction in base width since the ability of the structure to collect rainfall was reduced by these changes. SEI was unwilling to revise the design of the structure without substantial additional cost to WisDOT. Unable to provide additional project funding, WisDOT did not require that the revisions be made.
Another revision which SEI made to the preliminary design was the removal of additional material from the interior of the vertical support members.

Also, SEI proposed that the plastic frame would be black. WisDOT preferred brown, but SEI would not provide the brown pigment without substantial additional reimbursement. The black color was accepted after WisDOT determined that the cost of pigmenting the plastic was excessive.

The soil fill for the structure was specified as a mixture of topsoil, sand, and peat moss in a 1:1:1 ratio by volume. Leaf mulch was allowed as a substitute for peat moss.

The original planting plan included various species of evergreen and deciduous shrubs, vines, roses, ground covers, and herbaceous perennials (see Figure 6, page 19).

CONSTRUCTION

Initial site clearing and foundation preparation began on April 18, 1994. Thick shrubs which were blocking residents' view of the freeway required removal. Several large trees were also removed from the site. A number of trees were left in place between the barrier and the residences.

After the site was graded, the geogrid and 450 mm (18 in.) of crushed limestone were placed. The limestone was compacted with a vibrating roller and leveled.

Assembly of the plastic frame began on May 20, 1994. As each layer of the frame was assembled it was filled with soil. The soil mixture was comprised of 70% topsoil and 30% peat. The soil mixture differed from the project specification but was acceptable to WisDOT and the SEI representative who was on site to supervise the initial assembly of the structure.

Several methods of compaction were investigated during the initial filling process. A jumping jack type compactor was used and provided good compaction, but caused the horizontal plastic members to deform and bow outwards. A plate compactor was used at high intensity with similar results. The selected method was a plate compactor at low intensity. This method provided sufficient soil compaction without deforming the plastic frame. This method was acceptable to WisDOT and the SEI representative on-site.

Assembly of the structure proceeded without difficulty and was completed in early June, 1994.

Construction activities are shown in Photographs 1 through 6 (pages 24 through 26). The completed barrier is shown in Photographs 7 through 10 (pages 27 and 28).

BARRIER PERFORMANCE

INITIAL BARRIER PERFORMANCE

Structural

Two problems with the structure became apparent very soon after its completion. The first was a bulge in the upper tiers of the northeast end of the structure. The second was the loss of soil from within the structure.

The bulge became apparent after a plant watering. The upper 1/3 of the structure was somewhat saturated after the watering. Several days after the watering, it was discovered that the upper 1/3 of the structure was bulging out approximately 200 mm (8 in.) towards the northwest side. Ongoing measurement showed very little additional movement of the structure. It was determined that the shifting of the structure had stopped and there was no immediate concern that a structural failure would occur. Periodic measurements continued, but no repair measures were deemed necessary.

The loss of soil from within the structure was evident even as the assembly was completed. Soil began falling out of the structure, over the top of the horizontal members, creating a domino effect in areas above the original soil loss point. See Figures 7 through 10 (pages 20 and 21).

Figure 7 shows a partial cross-section of the barrier as it was completed. As shown in Figure 8, the soil on the inclined surface of some planting cells began falling out. The soil gradually fell out of the front of approximately 20-30% of the cells until the soil surface reached the angle of repose. This in turn allowed soil from behind the horizontal member above to begin falling out, undermining the next highest planting cell. This is illustrated in Figure 9.

Eventually, whole sections of the structure were emptied of soil, and other sections were left with large voids, as shown in Figure 10 and Photographs 11 through 14 (pages 29 and 30). The cells were refilled but the same results occurred.

It was determined that the vegetation should be planted in hope that the plant cover and root system would eliminate the soil containment problem. This effort, however, was not effective and several hundred plants were lost. The plants ended up falling out of the structure along with the soil.

In April, 1995, the horizontal members of the structure were retrofit with extensions, as shown in Photograph 15 (page 30) and Figure 11 (page 22). The 150 mm (6 in.) wide plastic extensions allowed the soil to sit at the angle of repose while confining the soil from the planting cell above. This procedure effectively eliminated soil loss from the structure.

Vegetation

The structure contained 5419 cells for planting. Each individual cell measured approximately 914 mm (3 feet) wide by 200 mm (8 in.) high.

Planting began in early June of 1994, following the assembly of the structure. As noted earlier, soil loss was already evident when planting began.

After several days of planting, concern was raised by the supplier of the plants regarding the appropriate selection of species. The supplier believed that many of the plants originally specified were inappropriate because of the harsh conditions to which they would be exposed. Low moisture, strong winds, and the possibility that much of the soil in the structure could freeze solid during the winter required selecting hardier species than originally specified.

Following consultation with the plant supplier, landscape contractor, WisDOT landscape architects, and HNTB (the original planting plan designer), the decision was made to substantially revise the planting plan.

A cooperative effort between those listed above and District 2 staff resulted in a more appropriate plant selection and design for the structure. Figure 12 (page 23) shows the revised plant selections.

Planting activities resumed in mid-September and were completed by the end of October, 1994. Weather conditions and temperatures were favorable and there was only minimal difficulty completing the planting, except for the soil loss problem which was not corrected until the following spring.

Many of the plants were in a dormant state when planted. Most plants which were not dormant appeared healthy and readily recovered from the shock of transplant. A total of 13,877 plants were planted in the wall during the fall of 1994.

YEAR ONE ASSESSMENT

During the later summer of 1995, the performance of the structure was evaluated. Durability of the plastic/soil structure itself and the condition of the vegetation were the major items evaluated.

Structural

Several structural concerns were identified during the first year of operation. These included bulging in the structure, soil loss, deflection of horizontal members, deflection of vertical supports, leaning of the entire structure, and breakage of individual plastic members.

Bulging towards the northwest side of the structure was discussed earlier in this report. Periodic measurements continued to show negligible additional deflection.

Soil loss from the structure was also discussed earlier in this report. The plastic extensions which were attached to the horizontal members effectively eliminated soil loss from the planting compartments. However, cracks became evident in a small number of the plastic extensions and several of the screws which were fastening the extensions came loose from the horizontal members. This did not appear to be a significant concern and required only that the extensions be replaced or refastened.

A small amount of deflection or warping in the horizontal members was visible. This was due to the flexible nature of the recycled plastic itself and was expected to occur. There was little concern that this would have a detrimental effect on the structural integrity of the barrier.

Deflection in the vertical supports was also visible. The individual supports appeared to be warping from the lateral force of the interlocking horizontal members. At the completion of construction the stacked vertical supports were in a true vertical position. After one year, the stacked supports appeared snake-like, curving from side to side. The degree to which this distortion had occurred varied throughout the structure.

In addition to the distortion of the individual vertical supports, large sections of the structure were leaning toward the northeast. In some sections, the vertical supports were out of plumb by as much as 325 mm (13 in.) when measured from the top to the bottom of the structure. There was little concern that the structure would tip over, since the northeast end of the structure butted up against a large concrete post for the standard post and panel noise barrier to the north.

The last structural concern was the breakage of part of one horizontal member. The interlocking tab which holds the horizontal member to the vertical support had broken off. The horizontal member remained in place although it was not interlocked with the vertical support.

Of greater concern was the physical make-up of the broken horizontal member. At the place of the break, the interior was almost entirely devoid of plastic. Apparently, a large air bubble had settled in this location during the fabrication process. Approximately 6.3 mm (1/4-in.) of solid plastic made up the exterior of the 50 mm (2-in.) thick section. Another 6.3 mm (1/4-in.) was made up of very porous plastic between the solid plastic exterior and the air bubble. The member was structurally incapable of handling the applied forces. Photographs 16 and 17 (page 31) show the broken section of the horizontal member.

In an effort to investigate whether other structural members had similar fabrication defects, several horizontal members which were left over from construction were sawed into small sections. No other defects were found.

There was concern that the distortion of the vertical members, leaning of the structure, and breakage of the individual members could continue, possibly causing a structural failure. No remedial actions were recommended following the first year review. However, it was recommended the structure be closely monitored for any additional movement, distortion, or breakage.

Vegetation

Approximately 4900 plants did not survive the first growing season (spring to fall of 1995). In fact, about half of these never even sprouted in the spring of 1995. An additional 2400 plants required replacement after they fell out of the structure due to the soil containment problem discussed earlier in this report.

Major concerns which were identified during the first growing season were the structure's inability to capture rainfall and retain moisture, watering difficulties, weed competition, and plant mortality.

The design of the structure was not conducive to capturing enough rainfall to support plant life. Only small areas of the sloped sections captured rainfall during calm conditions. When the wind blew towards one side of the structure, the side facing the wind retained some rainfall but the opposite side remained dry. The vertical sections of the wall received only minimal rainfall and only when there was a strong wind-driven rain.

When rainfall did reach the soil surface, amounts were rarely sufficient to achieve soil saturation at substantial depths. The upper and lower 1/3 of the wall captured and retained more moisture than the middle 1/3.

Since rainfall did not provide adequate moisture, watering was required to keep the vegetation alive. The most critical time for watering was during the spring when the newly planted vegetation was sprouting.

A decision was made during the feasibility study phase of this project to forego an irrigation system because its inclusion would make living noise barriers impractical in Wisconsin due to continued maintenance responsibilities and costs. Since there was no accessible water source near the structure, a water truck was needed to provide an adequate supply of water.

Watering the plants was the responsibility of the landscape contractor for the first two growing seasons. However, the contractor was seldom responsive to requests for watering made by WisDOT staff. The methods used by the contractor were seldom effective, since only the surface of the soil was wet and saturation to a substantial depth was not achieved. Much of the watering was done during the middle of the day when most of the moisture evaporated.

Plant losses were approximately 35% during the first year, due largely to the lack of sufficient moisture. Several entire species which were planted as small cuttings or root stock never sprouted. This may also be attributed to the harsh conditions during the first winter or possibly to immaturity of the root stock at the time of planting.

Several species which performed exceptionally well during the first year included: Sedum (all species), Phlox, Fragrant Sumac, Alpine Current, Engelmann Ivy, Lamium, Artemesia, Daylily, and some Hostas. Species which survived but were not thriving included the grasses, Solidago, Yarrow, Boston Ivy, Bittersweet, Arctic Willow, Common Snowberry, Coral Berry, Astilbe, Fleece Flower, and some Hostas. The rest of the species performed very poorly or never sprouted.

Weeds sprouted and took over many of the planting compartments where plants did not sprout or where they were not thriving. The additional competition of the weeds crowded out many of the less hardy plants. The entire structure was weeded once during the first year. This was not enough to control the prolific weed growth and many sections of the structure became overgrown with weeds.

Replacement planting took place during the summer of 1995. The species which were established and performed generally well were replaced, in kind, when individual specimens died. Species which did not perform well were replaced with either Sedum species or Lamium, both of which performed well during the first growing season.

The overall aesthetic appearance of the structure varied from section to section and was also dependent upon the distance from which it was viewed. A close-up view revealed the weed domination in certain sections, whereas the wall was attractive in sections where certain planted species were doing well. Especially attractive were areas planted with Sedum, Phlox (when in bloom), Fragrant Sumac, or Alpine Current. A view from 30-60 meters (100-200 feet) away revealed a sparse vegetation cover. The black plastic framework was visible and the vegetation was not dense enough to screen it from view. Ironically, sections which were severely overgrown with weeds were most attractive from a far distance. These areas were green and the dense cover screened the plastic frame from view.

Public Perception

Initial public opinion of the project was positive, as was media coverage and political support. As construction progressed, several neighbors started to become irritated at the constant dust blowing from the wall. When the weed growth became visible, several neighbors became disgruntled with the progress of the project and developed an increasingly negative opinion.

The media provided positive newspaper articles and interviews when construction began on the wall. After the spring of 1995, when the media became aware of plant losses, weed problems, and soil containment problems, coverage became increasingly negative.

YEAR TWO ASSESSMENT

Periodic monitoring of the structure continued throughout 1995 and through the summer of 1996. The gradual deterioration of the plastic frame and poor condition of the majority of plants became major concerns by the end of summer, 1996.

Structural

As early as May of 1996, it became evident that the recycled plastic frame was not performing as expected. The vertical supports and horizontal members continued to deform. The vertical supports became increasingly curved and snake-like. See Photographs 18 and 19 on page 32. The horizontal members were becoming increasingly warped under the weight of the soil. The deformation was worse on the southeast side of the structure, although the northwest side was visibly deformed also. The southeast side was exposed to much more sunlight and higher temperatures than the northwest side.

Breaks in more of the plastic members were also observed. The sections of the vertical supports which directly supported the horizontal members began to shear off. After the supports sheared off, the horizontal members would fall onto the next lower level. In one localized section, several supports in a row broke off and two of the horizontal members fell off of the structure. The soil then began falling out from the interior of the structure onto the ground. This localized breakage progressed until there was a hole in the structure measuring approximately 4 meters (13 feet) x 2 meters (6.5 feet), and much of the soil which had filled that area was piled at the base of the structure. See Photographs 20 through 24 (pages 32 through 34).

Breakage of vertical supports and the ends of horizontal members was evident at random locations throughout the structure, but almost all were on the southeast side. It was apparent that the plastic frame was progressively deteriorating at an accelerated rate.

The plastic extensions to the horizontal members were cracking and many of the fasteners were pulling out (Photograph 25, page 34). When the extensions cracked or separated from the horizontal member, the soil would again begin falling out. This resulted in many small soil voids throughout the structure.

The soil core of the structure appeared to be drying out and some shrinkage in the soil mass was evident. When digging back into the soil mass a slight separation between the soil and sections of the vertical supports could be felt. The soil felt dry and, in the area where several supports had broken, the inside of the soil mass was observed to have a low moisture content.

At almost all shear and breakage locations, air voids and porosity were observed in the interior of the plastic members. Some of the members had as little as 6.3 mm (1/4-in.) of solid plastic around the periphery, with the remainder of the section made up of an air bubble or very porous plastic. This was the major cause of these failures and points to a quality control problem during manufacturing. Photographs 26 and 27 (page 35) show a sheared off portion of a vertical support.

WisDOT began developing repair alternatives and considering whether to continue the experimental project. As early as August, 1996, there was concern that the structure would continue to deteriorate and was beyond repair.

Vegetation

A spring, 1996 assessment of vegetation survival was positive. On the southeast side of the wall, most species, including replacements, were sprouting and showing signs of new growth. The vegetation on the northwest side was slower to respond due to the minimal sun exposure. However, as spring progressed, most plants began sprouting .

By late June the condition of the plants had deteriorated significantly. Only 40-50% of the plants were alive and very few of those were thriving. The spring of 1996 was fairly dry and the rainfall which did occur rarely made it into the planting cells. The landscape contractor responsible for care of the plants was not observed watering during the spring or summer. Lack of moisture appeared to be the cause of poor vegetation performance.

Weed growth continued to be a problem. Prolific weed growth was observed throughout the planted areas. One section of the wall where a number of Sedum species were actually thriving became so overgrown with weeds that the Sedum species were not visible. The contractor responsible for weeding informed the WisDOT that his personnel could not work on the structure due to its structural instability.

Weed growth on the residential side was very disturbing to some of the residents. Aesthetically, it was unacceptable and they were also concerned that the weeds would invade their lawns.

There were several species that continued to perform well. Sedum species which had survived through the first growing season continued to do well, unless they were totally overgrown with weeds. Sedum was planted mostly in the upper half of the structure and only on the southeast (freeway, sunny) side. Phlox Subulata performed well in the spring, but was damaged by the continually dry conditions. Fragrant Sumac planted in the lower 1/3 on the southeast side also performed well.

On the northwest side (shady, residential), the Englemann Ivy and Alpine Current performed very well. These were planted mostly in the lower 1/2. Most of the Hostas and Daylillies that survived the first growing season continued to live, but were not thriving. Photographs 28 through 31 (pages 36 and 37) show the vegetation growth during the summer of 1996.

Public Perception

Public opinion of the project continued to deteriorate during the summer of 1996. Some residents were very dissatisfied with the general appearance, the extensive weed growth, and the dust which had been blown into their homes.

Media coverage became increasingly negative and focused on the residents' complaints as well as the additional costs of plant replacements and structural repairs.

STRUCTURE COLLAPSE

In late August, 1996, a portion of the structure collapsed. The top 1.8 to 3 meters (6 to 10 feet) of the northeastern-most 30 meters (100 feet) fell off into the ditch next to the freeway. This appeared to be a very sudden collapse, although there were no witnesses. Two weeks after the initial collapse, an additional 30 meter (100-foot) section collapsed into the ditch as well. The collapsed sections are shown in Photographs 32 and 33 (page 38).

Several inspections of the collapsed area were conducted to determine the cause. Staff from the FHWA, HNTB, and WisDOT analyzed the collapsed area and the remaining sections which were still standing.

Upon inspection, many of the vertical support members appeared to be torn in half, indicating that the cause of the collapse was directly related to failure of the plastic support system. However, several contributing factors were identified:

- Porosity and large air bubbles were evident in almost all of the broken plastic support members. A lack of quality control during the manufacturing process may have caused this to occur. The strength in the air bubble areas was greatly reduced and these sections were more susceptible to failure than the rest of the members. Broken sections showing air bubbles and porosity are shown in Photographs 34 and 35 (page 39).

- Soil voids reduced the bearing capacity in the middle third of the structure. Since the soil and plastic frame were designed to work as one system, the support strength was greatly reduced after soil in the mid-section began falling out. Only the plastic framework was left to support the upper section of the soil core. This contributed to the excessive deformation and ultimate failure of some of the plastic supports.

- The moisture content in the soil core was very low, causing the entire core to shrink. As the soil core shrunk and consolidated, lateral support for the vertical members, provided by contact with the surrounding soil mass, was greatly reduced. The downward force of the soil mass continued to be applied to the horizontal planks, which were attached at each end to the vertical members. This resulted in the movement and deformation of the vertical members, causing them to appear "snake-like" and out of plumb, instead of straight and vertical. This also may have caused excessive stresses to be applied to the plastic framework contributing to the failure.

- High temperatures caused by the sun appear to have contributed to the weakening of the plastic framework. Deformation of the plastic was much more extensive on the sunny side than on the shaded side, and breakage of the horizontal members occurred only on the sunny side. The black plastic was warm on sunny winter days and was very hot on sunny summer days. The temperature of the plastic on the shaded side remained at approximately the same temperature as the air.

The WisDOT, in consultation with the FHWA, decided to discontinue the living noise barrier project following the second collapse. On September 30, 1996, contractors for the WisDOT began removing the remaining plastic framework and shaping the soil into an earth berm. Most of the plants were lost. However, approximately 200 shrubs were salvaged and planted on the berm.

Several attempts were made to contact the manufacturer during this period of time. Several letters from attorneys representing SEI were received, informing the WisDOT that the corporation had filed for bankruptcy and had been dissolved .

PROJECT COSTS

The final project costs are shown below:

STRUCTURAL ITEMS:	
Recywall frame and soil core	$ 225,837.30
Geo-grid Reinforcement	3,978.31
Attachment to Post & Panel wall	1,374.90
Horizontal Plank Extensions	54,712.30
TOTAL STRUCTURAL COST	**$ 285,902.81**
TOTAL VEGETATION COST	**+ $ 109,981.43**
TOTAL COST	**$ 395,884.24**

TOTAL COST PER SQ. METER= $415.00 ($38.55/SQ. FOOT)

Over the last decade, the cost for standard post and panel noise barriers in Wisconsin has averaged approximately $168.50 per square meter ($15.65 per square foot).

OBSERVATIONS & CONCLUSIONS

1. The geometric design of the Recywall was not conducive to capturing sufficient rainfall for healthy plant growth. Steep side slopes prohibited moisture from entering the planting compartments.

2. The design of the plastic framework was not sufficient for holding the soil core in place. The inability of the framework to retain the soil led to large voids in the soil core. The voided areas may have been a contributing factor to the structural failure.

3. The recycled plastic members contained internal air bubbles and porosity. Areas which failed were observed to contain excessive amounts of air voids instead of solid plastic. The lack of structural integrity of the material appears to be the major factor in the failure.

4. A majority of plant species were unable to survive the harsh conditions to which they were exposed. Extreme cold, wind, and lack of sufficient moisture did not allow most plants to survive.

5. From November to late June, there was no vegetation to hide the plastic framework. During more than half of the year there was no potential for covering the unattractive frame.

6. Weed growth was excessive and could not be controlled without an extensive manpower commitment. Weed growth was unattractive and unacceptable to the neighbors .

7. Several plant species were hardy enough to survive the harsh conditions.

8. The cost of the living noise barriers was 146% more than a standard post and panel type barrier.

SUMMARY & RECOMMENDATIONS

Living noise barriers are not cost-effective and should not be pursued by WisDOT. The extensive commitment to maintenance activities, particularly watering and weeding, precludes using this type of barrier on a widespread basis. Without such a commitment, the aesthetic appeal of a living noise barrier is minimal. Even with such a commitment, the aesthetic appeal would still be limited by the short growing season in Wisconsin. Furthermore, the construction costs are excessive when compared with standard post and panel noise barriers.

Based on the strength and temperature characteristics of plastic, WisDOT's experience with Recywall, and other instances where plastics were used in a structural capacity, it is the recommendation that non-reinforced plastics, either virgin or recycled, not be used as structural members of any kind.

Figure 1: General Location

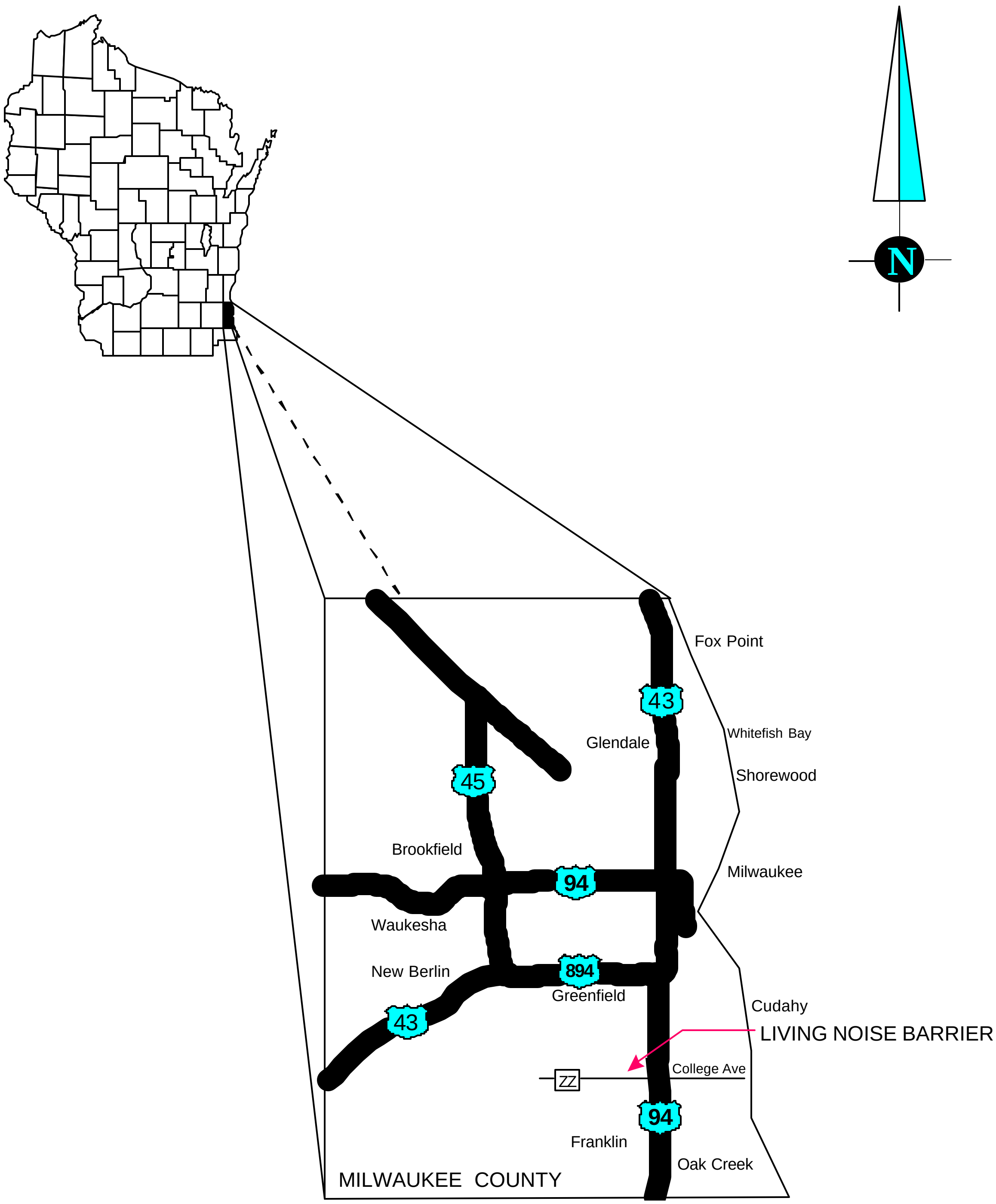


Figure 2: Specific Location

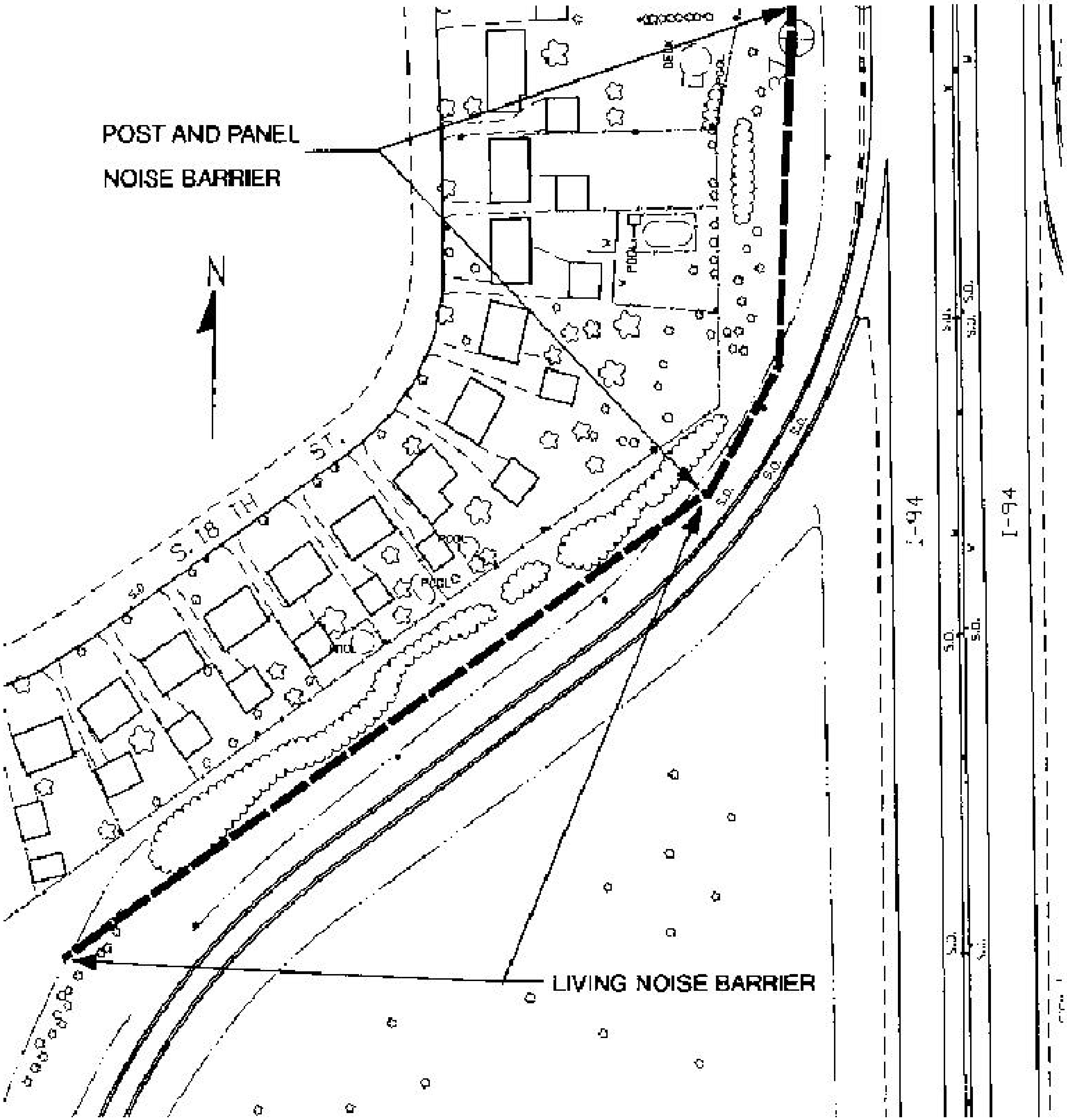
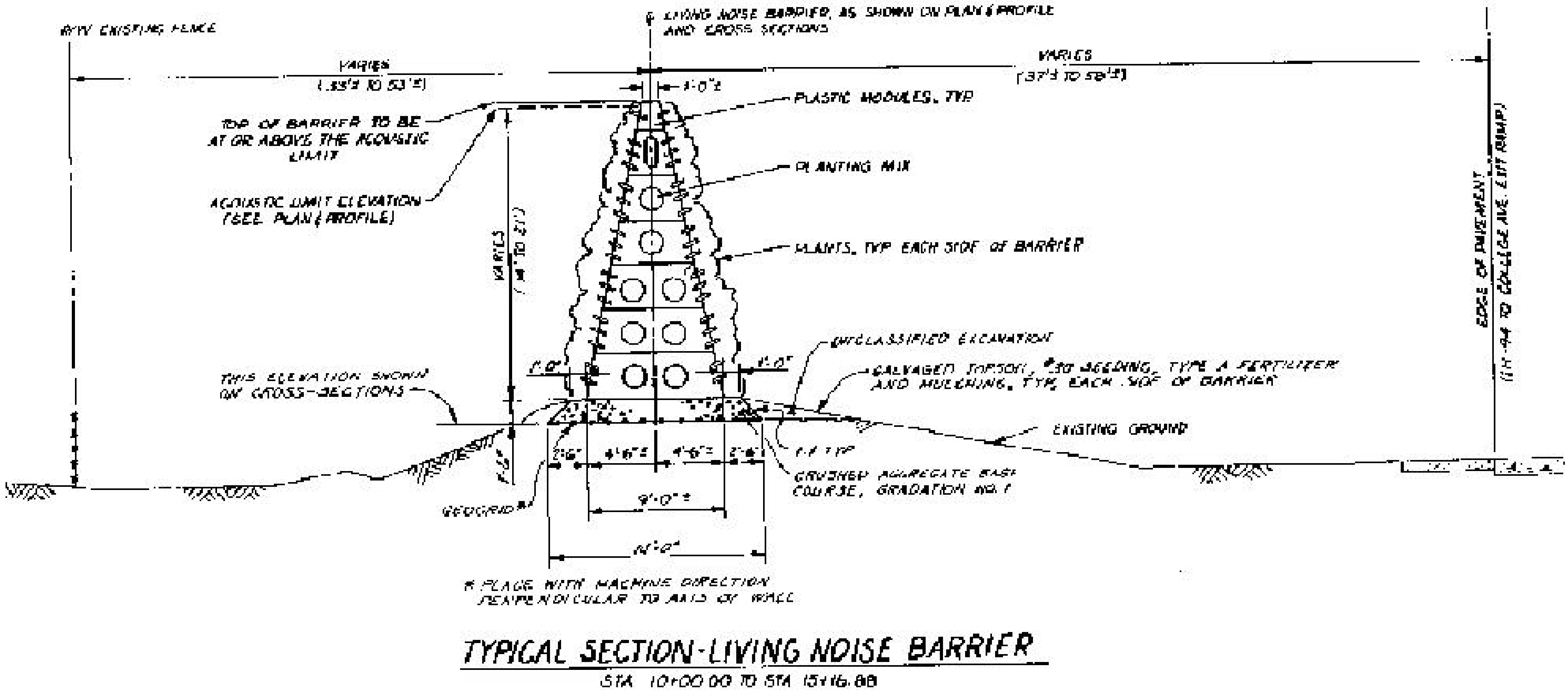


Figure 3: Preliminary Conceptual Design



TYPICAL SECTION-LIVING NOISE BARRIER

STA 10+00.00 TO STA 15+16.88

Figure 4: Final Structural Design

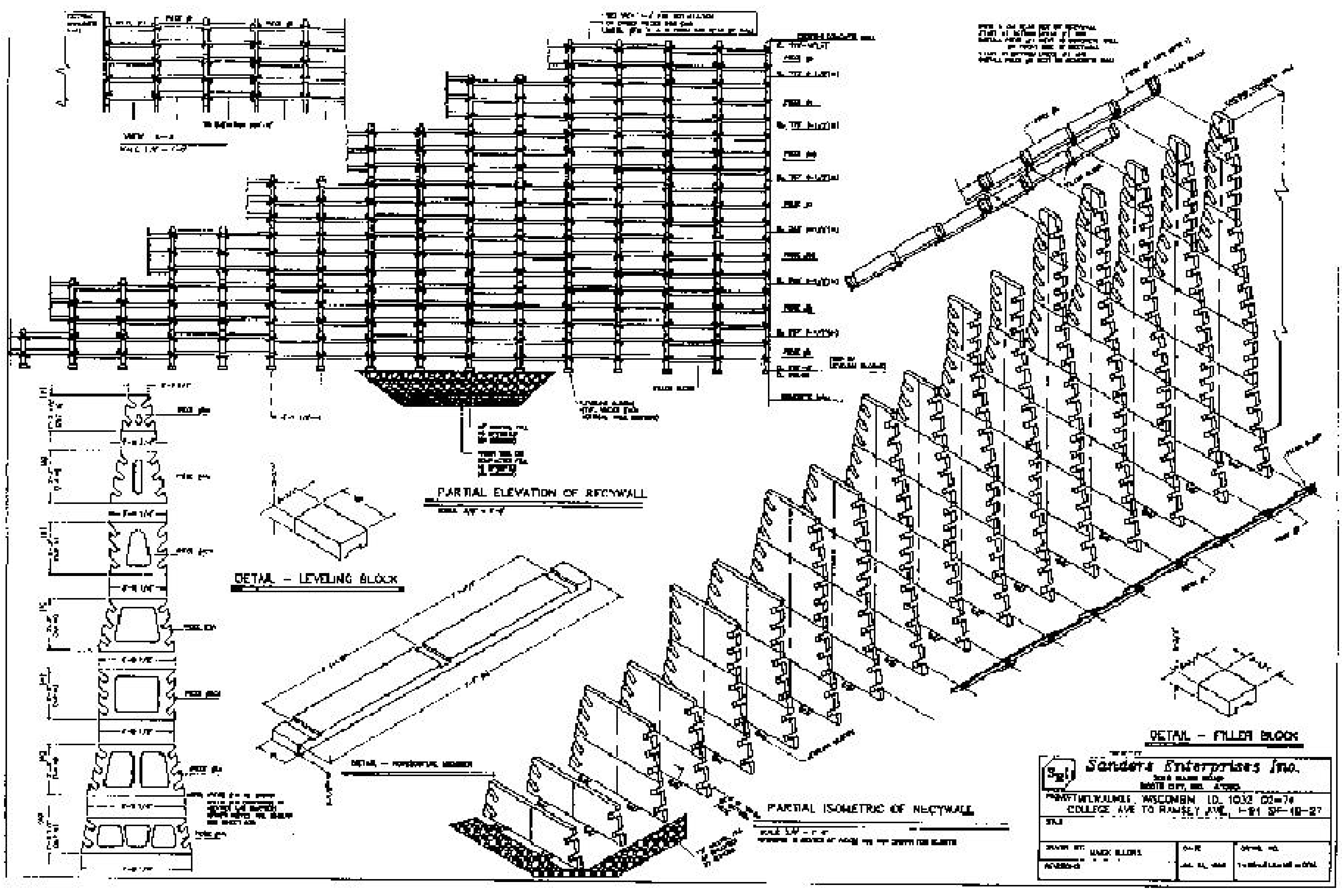


Figure 5: Final Design of Structural Members

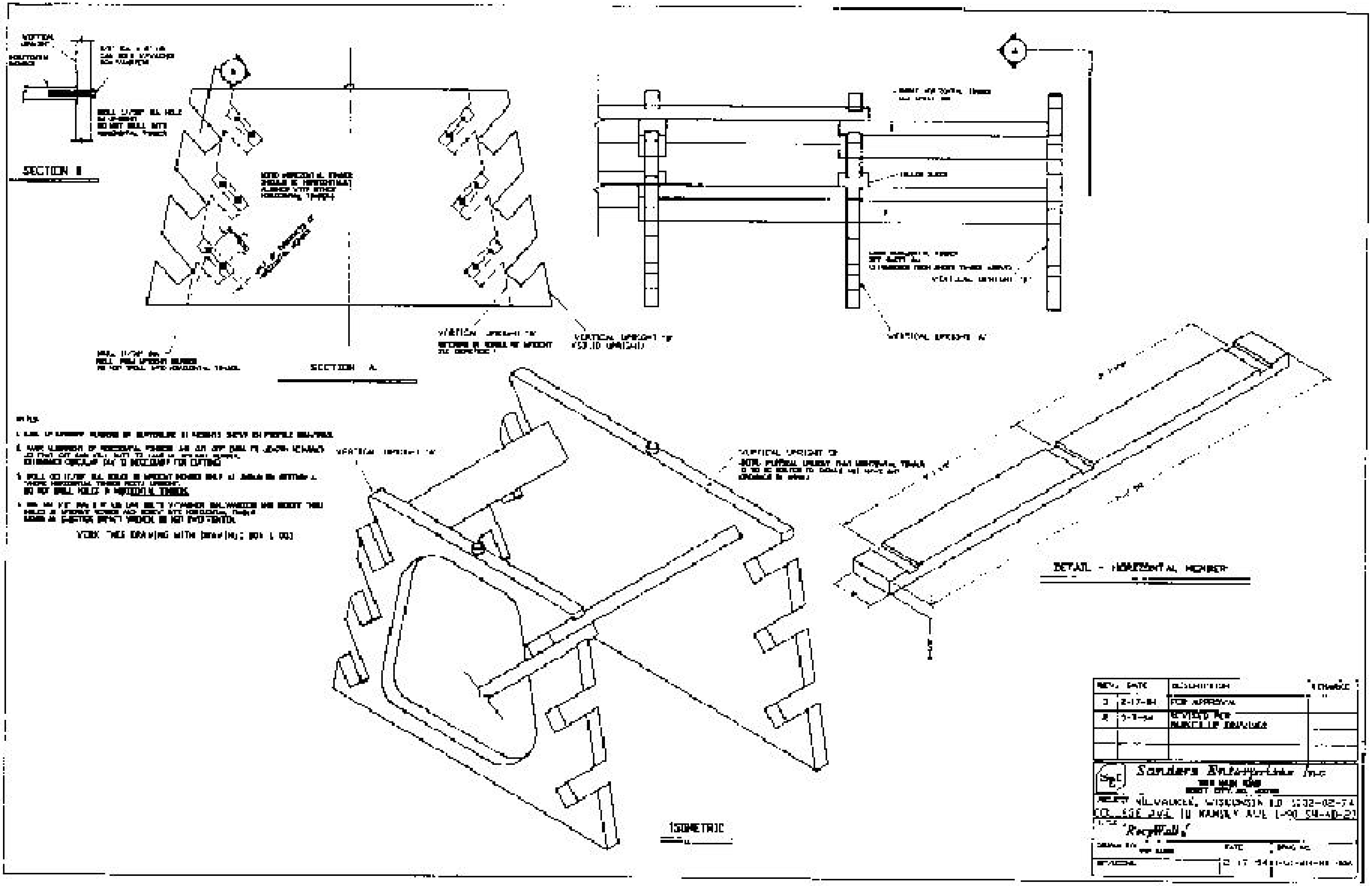


Figure 6: Original Planting Plan

PROPOSED PLANTINGS

PLANTING DATA SYMBOL	COMMON NAME	PROPOSED PLANTINGS SCIENTIFIC NAME	AAN TYPE	AVERAGE MATURE HEIGHT	SIZE HANDLING WHEN PLANTED	MINIMUM HOLE SIZE DIA X DEPTH*	MINIMUM ROOT SPREAD	FERTILIZER PACKETS REQUIRED	RODENT PROTECTION REQUIRED	QUAN
DECIDUOUS SHRUBS										
CN	COMMON NINEBARK	PHYSOCARPUS OPULIFOLIUS	3	24"–36"	12" HT. B.R.	18"*	11"	2	NO	176
GFS	GRO-LOW FRAGRANT SUMAC	RHUS AROMATICA 'GRO-LOW'	3	24"–36"	12" HT. B.R.	18"*	11"	2	NO	842
IC	INDIANCURRANT CORALBERRY	SYMPHORICARPUS ORBICULATUS	3	24"–36"	12" HT. B.R.	18"*	11"	2	NO	290
NWE	MORAINE WINGED EUONYMUS	EUONYMUS ALATA 'MORAINE STRAIN'	4	24"–36"	12" HT. B.R.	18"*	11"	2	NO	708
SP	SIBERIAN PEASHRUB	CARAGANA ARBORESCENS	4	24"–36"	12" HT. B.R.	18"*	11"	2	NO	390
EVERGREEN SHRUBS										
BRJ	BLUE RUG JUNIPER	JUNIPERUS HORIZONTALIS 'WILTONII'	1	12"–18"	12" SPD. C.G.	18"*	11"	2	NO	204
CJ	CREEPING JUNIPER	JUNIPERUS HORIZONTALIS	1	12"–18"	12" SPD. C.G.	18"*	11"	2	NO	400
JGJ	JAPANESE GARDEN JUNIPER	JUNIPERUS CHINENSIS VAR. PROCUMBENS	1	12"–18"	12" SPD. C.G.	18"*	11"	2	NO	750
ROSE GRADES										
FHR	FATHER HUGO ROSE	ROSA HUGONIS	1 1/2	5'–6' SPD.	12" HT. B.R.	18"*	11"	2	NO	120
MR	MEADOW ROSE	ROSA CAROLINA	1 1/2	24"–36"	12" HT. B.R.	18"*	11"	2	NO	330
PR	PRAIRIE ROSE	ROSA SETIGERA	1 1/2	24"–36"	12" HT. B.R.	18"*	11"	2	NO	400
VINES										
AB	AMERICAN BITTERSWEET	CELASTRUS SCANDENS	1	12"–15"	12" SPD. B.R.	12"*	10"	2	NO	754
ABK	ARCTIC BEAUTY KIWI	ACTINIDIA KOLOMIKTA	1	12"–15"	12" SPD. B.R.	12"*	10"	2	NO	752
JH	JAPANESE HONEYSUCKLE	LONICERA JAPONICA	1	12"–15"	12" SPD. B.R.	12"*	10"	2	NO	276
SAC	SWEET AUTUMN CLEMATIS	CLEMATIS MAXIMOWICZIANA	4	12"–15"	12" SPD. C.G.	12"*	10"	2	NO	776

PROPOSED PLANTINGS

PLANTING DATA SYMBOL	COMMON NAME	PROPOSED PLANTINGS SCIENTIFIC NAME	AAN(1) TYPE	AVERAGE MATURE HEIGHT	SIZE HANDLING WHEN PLANTED	MINIMUM HOLE SIZE DIA. X DEPTH*	MINIMUM ROOT SPREAD	FERTILIZER PACKETS REQUIRED	RODENT PROTECTION REQUIRED	QUAN
GROUNDCOVER										
CC	CRANBERRY COTONEASTER	COTONEASTER APICULATUS	1	36"	12" C.G.	12"*	11"	5	NO	1226
PW	PURPLELEAF WINTERCREEPER	EUONYMUS FORTUNEI 'COLORATA'	4	24"–36"	12" B.R.	12"*	11"	5	NO	2600
SS	STONECROP SEDUM	SEDUM SPECIES	5	6"–8"	9" 4" POT	12"*	9"		NO	200
PRAIRIE PLANTS/WILD FLOWERS										
GG	GRAY GOLDENROD	SOLIDAGO NEMORALIS		24"	9" 4" POT	9"*			NO	2246
LB	LARGE BEARDSTONGUE	PENSTEMON GRANDIFLORUS		24"	9" 4" POT	9"*			NO	876
PB	PRAIRIE BUSHCLOVER	LESPEDEZA CAPITATA			9" 4" POT	9"*			NO	1236
SC	STIFF COREOPSIS	COREOPSIS PALMATA		24"–36"	9" 4" POT	9"*			NO	1086

NOTE: QUANTITIES REPRESENT PLANTINGS ON BOTH SIDES OF THE WALL.

ABBREVIATIONS:

AAN AMERICAN ASSOCIATION OF NURSERYMEN, AMERICAN STANDARD FOR NURSERY STOCK
B.R. BARE ROOT
C.G. CONTAINER GROWN
SPD. SPREAD
HT HEIGHT

* ALL HOLE DEPTHS SHOULD ADEQUATELY ACCOMODATE ROOTS, CONTAINERS & POTS.

Figure 7: Completed Cross Section

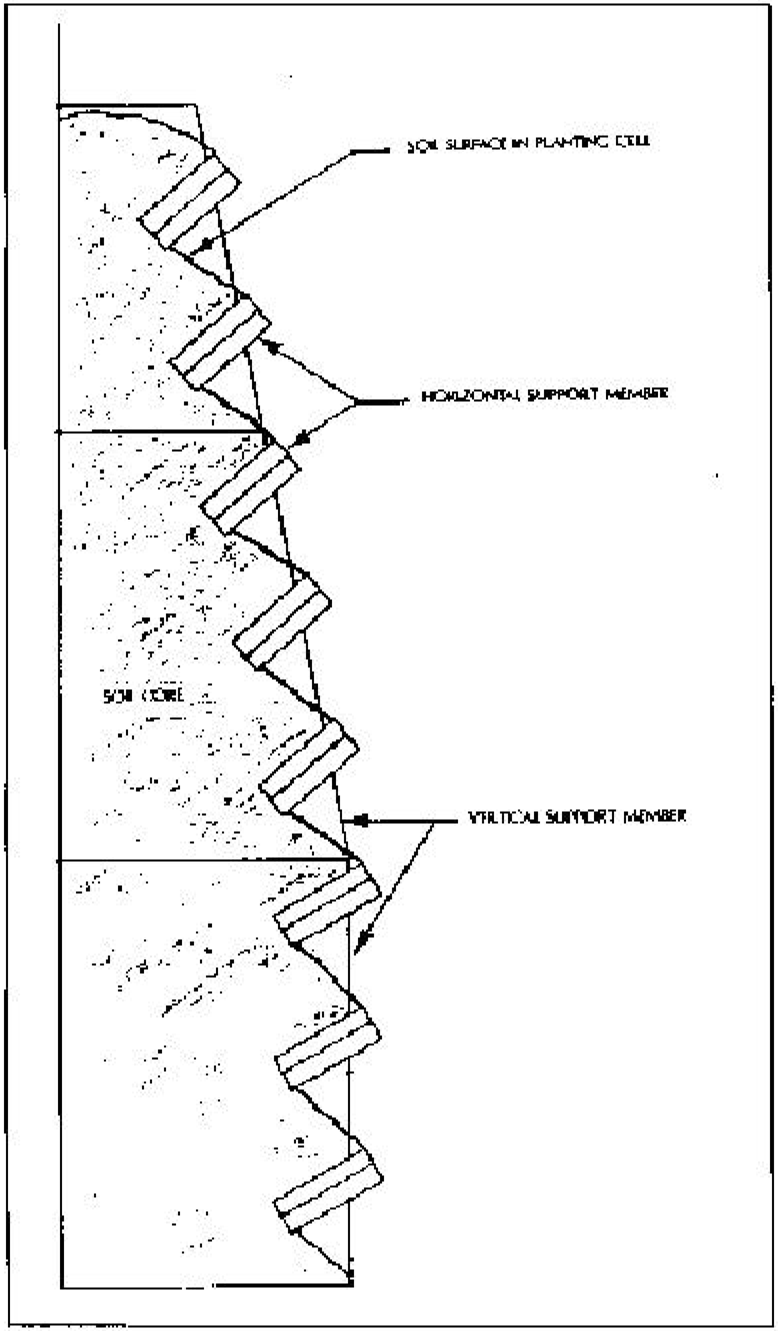


Figure 8: Soil Falling From Cells

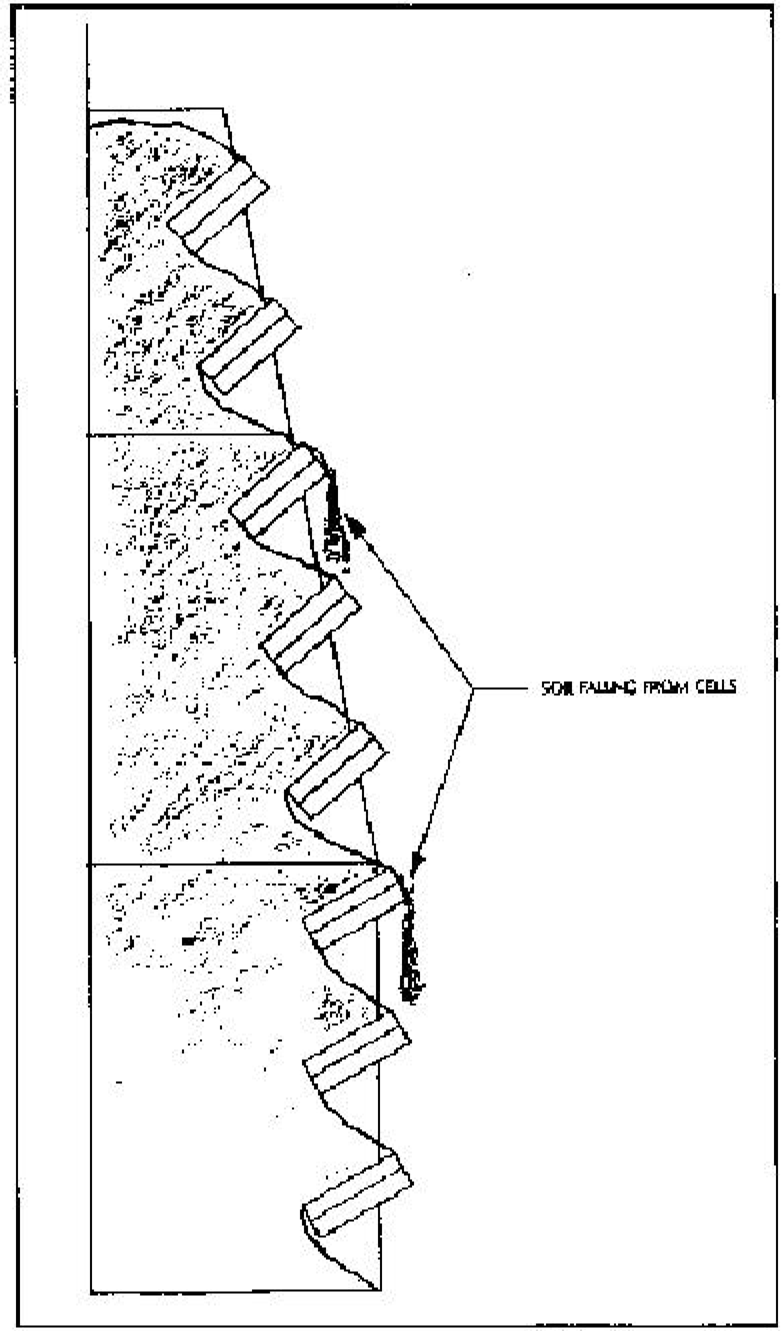


Figure 9: Soil at Angle of Repose

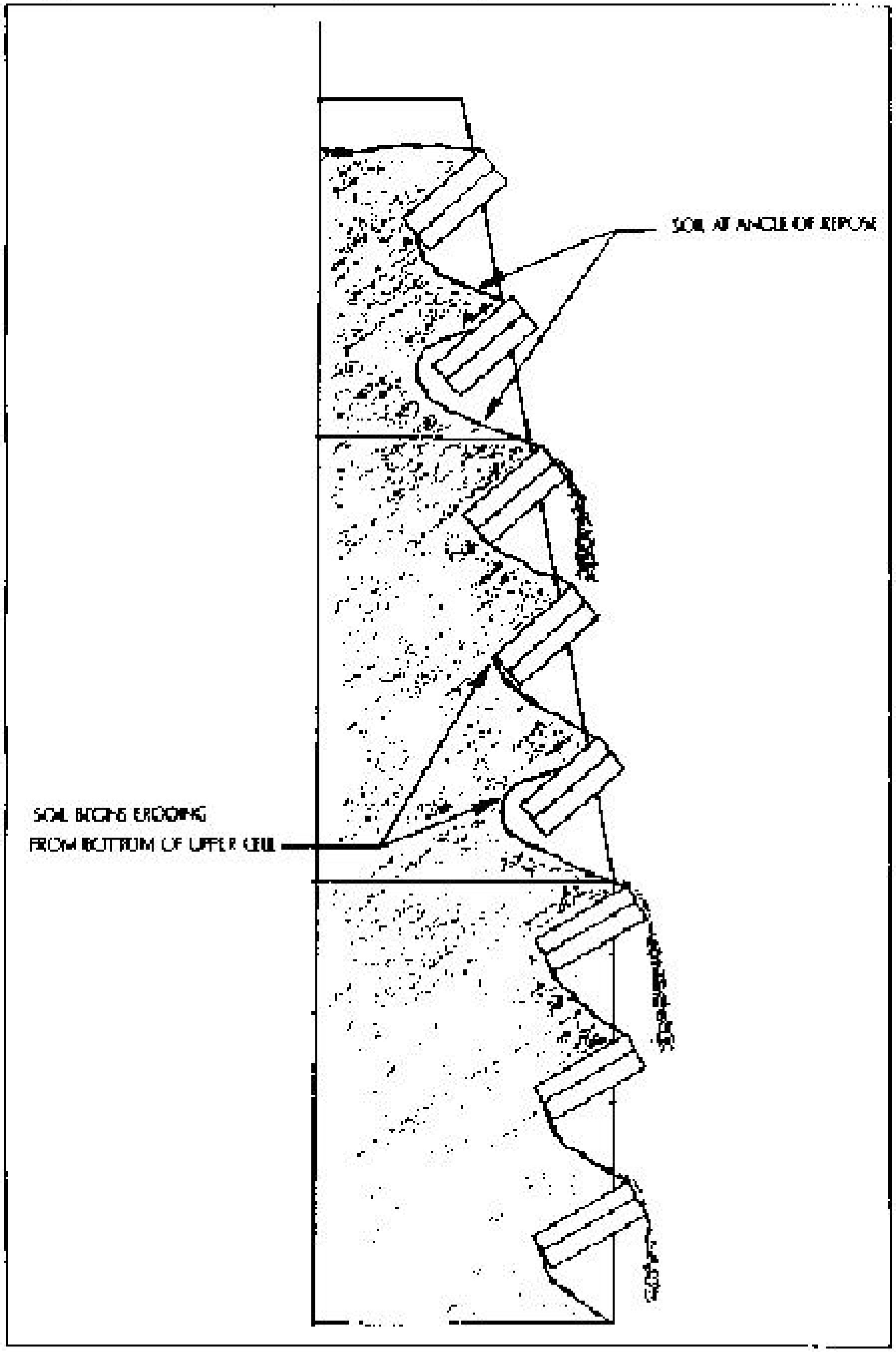


Figure 10: Large Voids in Soil Core

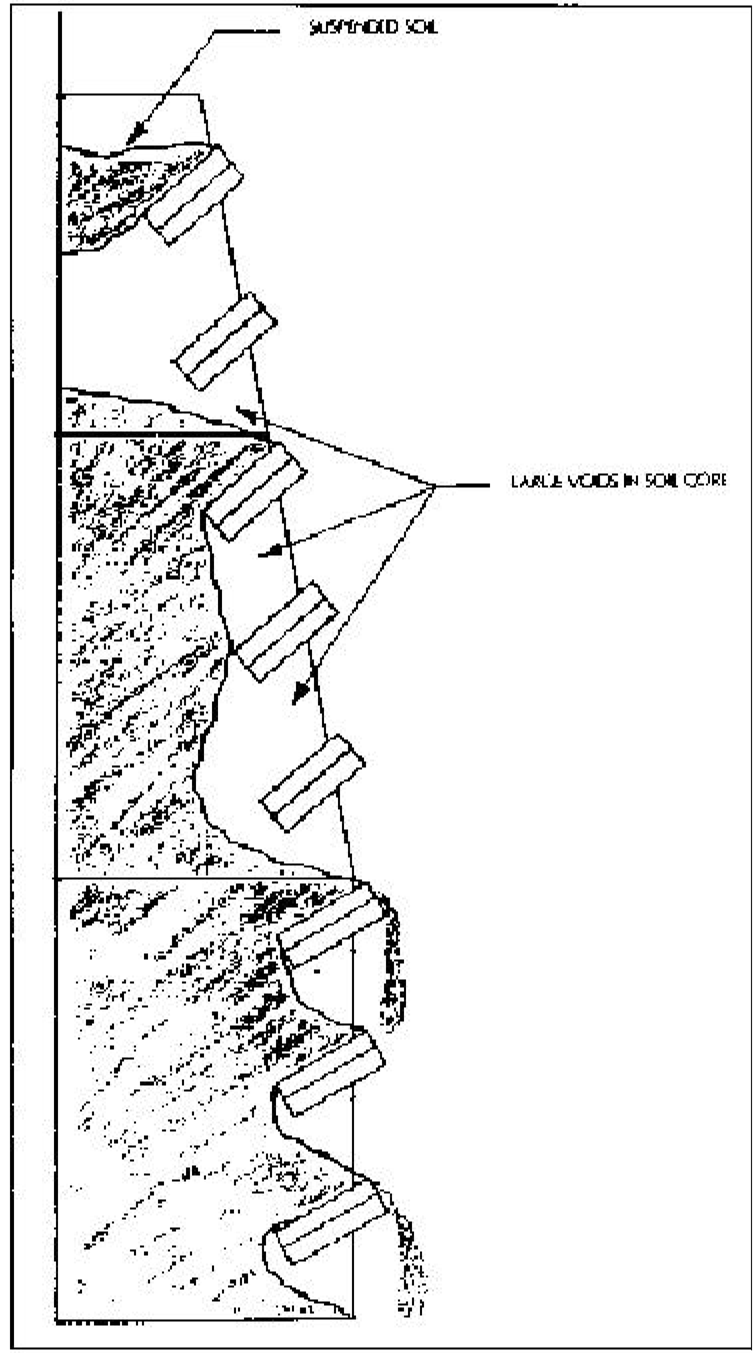


Figure 11: Structural Retrofit

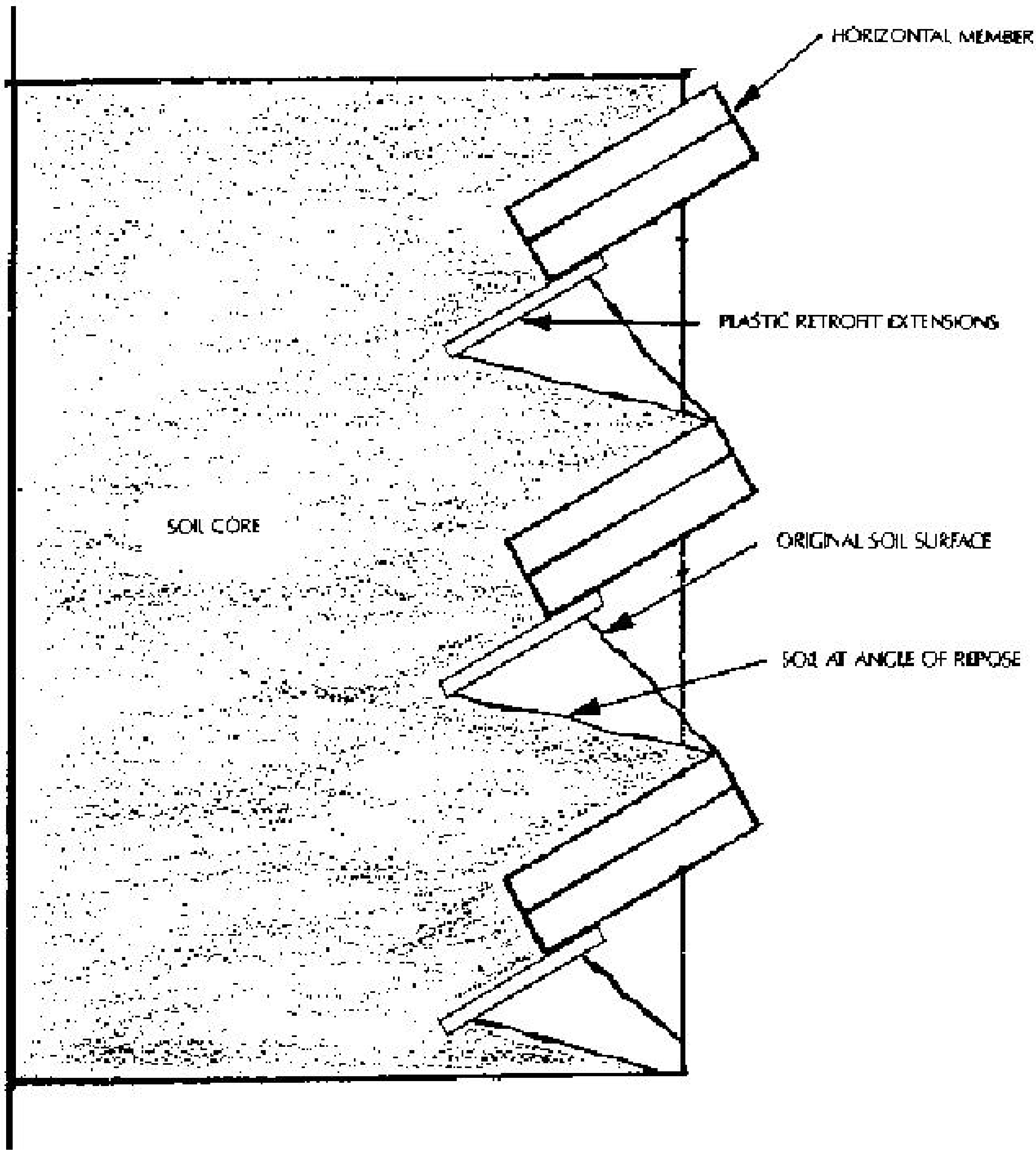


Figure 12: Revised Plant Selections

COMMON NAME	SCIENTIFIC NAME	AS BUILT QUANT.	SIZE WHEN PLANTED
DECIDUOUS SHRUBS			
FRAGRANT SUMAC	RHUS AROMATICA "GRO-LOW"	320	12" HT
ALPINE CURRANT	RIBES ALPINUM	348	2 GAL
DWARF ARCTIC WILLOW	SALIX PURPUREA "GRACILIS"	55	2 GAL
COMMON SNOWBERRY	SYMPHORICARPOS ALBUS	58	1 GAL
INDIANCURRANT CORALBERRY	SYMPHORICARPOS ORBICULATUS	194	12" HT
EVERGREEN SHRUBS			
BLUE RUG JUNIPER	JUNIPERUS HORIZONTALIS "WILTONII"	119	12" SP
VINES			
AMERICAN BITTERSWEET	CELASTRUS SCANDENS	120	12" HT
ENGELMANN IVY	PARTHENOCISSUS QUINQUEFOLIA "ENGELMANII"	128	12" HT
BOSTON IVY	PARTHENOCISSUS TRICUSPIDATA	130	12" HT
PERENNIALS			
YARROW	ACHILLEA (MIXED SPECIES)	233	4" POT
COMMON WORMWOOD	ARTEMESIA ABSINTHIUM	157	4" POT
WHITE SAGE	ARTEMESIA LUDOVICIANA	108	4" POT
NEW ENGLAND ASTER	ASTER NOVAE - ANGLIAE (MIXED CULTIVARS)	117	1 GAL
FALSE SPIREA	ASTILBE (MIXED HYBRIDS)	232	4" POT
CANADA TICK-CLOVER	DESMODIUM CANADENSE	104	1 GAL
PURPLE CONEFLOWER	ECHINACEA PURPUREA	257	1 GAL
QUEEN OF THE MEADOW	FILIPENDULA ULMARIA "VARIEGATA"	87	DIVISION
DAYLILY	HEMEROCALLIS (MIXED SPECIES)	1164	4" POT
GROUND MASTER HOSTA	HOSTA "GROUND MASTER"	542	DIVISION
ROYAL STANDARD HOSTA	HOSTA PLANTAGINEA "ROYAL STANDARD"	600	DIVISION
RECTIFOLIA HOSTA	HOSTA RECTIFOLIA NAKAI	210	DIVISION
ABO MARGINATA HOSTA	HOSTA UNDULATA "ALBO MARGINATA"	927	DIVISION
LAMIUM	LAMIASTRUM GALEOBDOLON (MIXED CULTIVARS)	1180	2" POT
BLAZING STAR/GAYFEATHER	LIATRIS PYCNOSTACHYA	90	4" POT
MONEYWORT/LOOSESTRIFE	LYSIMACHIA VULGARIS	225	4" POT
BEE BALM/BERGAMOT	MONARDA DIDYMA (MIXED CULTIVARS)	534	4" POT
BEE BALM/BERGAMOT	MONARDA FISTULOSA	219	4" POT
EVENING PRIMROSE	OENOTHERA TETRAGONA	81	4" POT
CREEPING PHLOX	PHLOX SUBULATA	509	4" POT
FLEECEFLOWER	POLYGONUM AUBERTII	135	4" POT
GRAY HEAD CONEFLOWER	RATIBIDA PINNATA	81	4" POT
GOLDSTURM BLACK EYED SUSAN	RUDBECKIA FULGIDA "GOLDSTURM"	108	1 GAL
WEIN GOLD STONECROP	SEDUM FLORIFERUM "WEIHENSTEPHANER GOLD"	339	4" POT
STONECROP	SEDUM KAMTSCHATICUM "ELLACOMBIANUM"	156	4" POT
MIDDENDORF STONECROP	SEDUM KAMTSCHATICUM "MIDDENDORFIANUM"	290	1 GAL
AUTUMN JOY SEDUM	SEDUM PURPUREUM "AUTUMN JOY"	150	4" POT
STONECROP	SEDUM SARMENTOSUM	300	4" POT
STONECROP	SEDUM SEXANGULAR	250	4" POT
DRAGON'S BLOOD STONECROP	SEDUM SPECTABILE "DRAGON'S BLOOD"	214	1 GAL
GOLDENROD	SOLIDAGO (MIXED NATIVE SPECIES)	547	4" POT
PERIWINKLE	VINCA MINOR	243	3" POT
BUTTERFLY WEED	ASCLEPIAS TUBEROSA	39	4" POT
MONEYWORT	LYSIMACHIA NUMMULARIA	387	4" POT
WOOD FERN	DRYOPTERIS	412	1 GAL
ORNAMENTAL GRASSES			
BIG BLUESTEM	ANDROPOGON GERARDI	180	4" POT
LITTLE BLUESTEM	ANDROPOGON SCOPARIUS	178	4" POT
SIDEOATS GRAMA	BOUTELOUA CURTIPENDULA	121	4" POT
FEATHER REED GRASS	CALAMAGROSTIS ACUTIFLORA	150	DIVISION
TUFTED HAIR GRASS	DESCHAMPSIA CAESPITOSA "SCHOTTLAND"	357	DIVISION
SWITCH GRASS	PANICUM VIRGATUM	513	5" POT

Photograph 1: Erecting vertical supports on top of a crushed limestone base.

Photograph 2: Placing horizontal planks into vertical supports.

Photograph 3: Filling the recycled plastic frame with soil.

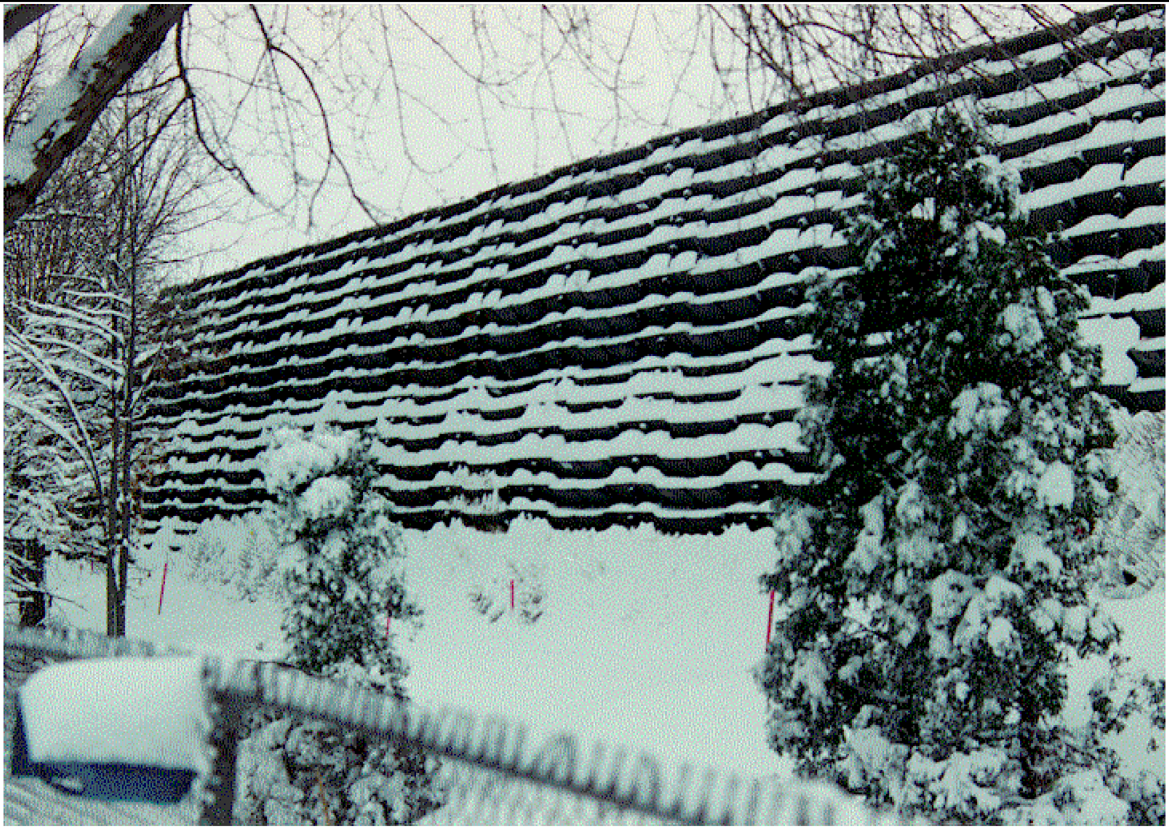
Photograph 4: Compacting the soil core.

Photograph 5: Successive tiers of the structure are assembled, filled, and compacted.

Photograph 6: The northeast end of the living noise barrier, abutting a concrete post for a standard post and panel noise barrier.

Photograph 7: Residential view of the barrier. Vegetation had been recently planted, but was dormant.

Photograph 8: Freeway view of the barrier.



Photograph 9: Winter view of residential side.

Photograph 10: Winter view of freeway side.

Photograph 11: Loss of soil is evident along the bottom of horizontal members.

Photograph 12: Large soil voids occurred throughout the structure.

Photograph 13: Large soil voids in planting cells

Photograph 14: Large soil voids in planting cells.

Photograph 15: Horizontal members with retrofitted extensions.

Photograph 16: Air bubbles and porosity are evident in a broken horizontal member.

Photograph 17: Air bubbles and porosity are evident in a broken horizontal member.

Photograph 18: Deformation in the vertical supports.

Photograph 19: Deformation in the vertical supports.

Photograph 20: Sections of the vertical supports which held the horizontal members in place began to break off.

Photograph 21: Sections of the vertical supports which held the horizontal members in place began to break off.

Photograph 22: After the vertical supports broke, the horizontal members began to fall out.

Photograph 23: After the vertical supports broke, the horizontal members began to fall out.

Photograph 24: The plastic frame continued to break, allowing the soil to fall out.

Photograph 25: As the vertical and horizontal members deformed, the plastic extensions began breaking away from the horizontal members.

Photographs 26 & 27: The interior of this piece of a vertical support does not contain any plastic. The plastic around the peri-phery contains many small air bubbleses.

Photograph 28: Vegetation growth during the summer of 1996.

Photograph 29: Vegetation growth during the summer of 1996.

Photograph 30: Vegetation growth during the summer of 1996.

Photograph 31: Vegetation growth during the summer of 1996.

Photograph 32: Collapsed section of the barrier.

Photograph 33: Collapsed section of the barrier.

Photograph 34: Large air bubbles and porous plastic were evident in the broken plastic frame.

Photograph 35: Large air bubbles and porous plastic were evident in the broken plastic frame.